

Sustainable NREL Baseline Data

National Renewable Energy Laboratory
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Overview of Sustainable NREL Project

Vision Statement

NREL will exemplify sustainability in an R&D organization by maximizing efficient use of all resources and serving as a positive force in economic, environmental, and community responsibility.

To be sustainable is to:

- Recognize the unique role of human beings as an integral part of the natural world.
- Mimic nature's cycles and use natural solutions.
- Eliminate waste - reduce, reuse, recycle, rebuy.
- Recognize and not exceed the "carrying capacity" of the environment.
- Recognize and use renewable energy and material resources at a rate that can be replenished.
- Balance environmental, economic, and social equity factors.

Goal for Capturing Baseline Data

In order for NREL to become a sustainable entity, an assessment of NREL's current practices needs to be made. From this information, 20-year goals for sustainability can be determined. All baseline data must capture the scope of what it means to be sustainable and will include the following:

Baseline data to be captured

- Site Planning and Utilities current practices
- Individual Building Energy Use
- Materials Use
- Transportation
- Water Use

Site Planning and Utilities

Site Energy Use

NREL currently uses two sources of energy - electricity and natural gas. Tables 1 and 2 below give the current breakdown of NREL's electricity and natural gas sources.

Electricity

Source of Electricity	kWh (1999)	% of Total Electricity
PSCo Non-'green' Energy	19,643,569	99.7%
Wind Energy (Purchased from PSCO)	48,000	0.3%
PSCO (Total Energy Purchased)	19,691,569	100%
NREL Produced Energy		
SERF PV's	24, 090	46.2%
OTF PV's	23,086	44.3%
NREL Sign PV	320	0.6%
Site Entrance Building PV	1,095	2.1%
Remote PV's (walkways, parking)*	3,542	6.8%
Biomass [§]	0	0%
Wind Energy from NWTC ^{§§}	0	0%
Total Electrical Energy Generated by NREL	52,133	100%
Grid Independent Energy Generated	4,957	9.5%
Grid Tied Energy Generated	47,176	90.5%
Total Electrical Energy Generated by NREL	52,133	100%
PSCo Green Energy	48,000	0.2%
PSCo Non-Green Energy	19,643,569	99.5%
NREL Produced Energy	52,133	0.3%
Total NREL Electrical Energy	19,743,702	100%

• Table 1 Electrical Energy (FY 99)

§CURRENTLY BIOMASS TECHNOLOGIES ARE NOT USED TO GENERATE POWER FOR NREL. IN THE FUTURE NREL MAY USE THE FIELD TEST LABORATORY'S THERMOCHEMICAL USER FACILITY TO GENERATE UP TO 30 KILOWATTS FROM BIOMASS.

§§ CURRENTLY THE WIND TURBINES AT THE NWTC ARE USED FOR EXPERIMENTATION ONLY AND NOT AS A POWER SOURCE. THE WIND TURBINES CAN PRODUCE 900KW BUT PRODUCE THIS AMOUNT AT VERY INFREQUENT INTERVALS.

*THIS NUMBER INCLUDES ALL SMALL STAND ALONE PV PANELS AROUND THE NREL CAMPUS. PV ENERGY PRODUCED BASED ON 1SQ. FT. OF PV = 20 KWH (BEN KROPOSKI ESTIMATE).

This works out to 200,674kWh per employee per year. Due to the nature of the NREL laboratory environment, electrical energy use is very sporadic. Some month's electrical use is extremely high; other months, it is low. All of NREL's produced energy is green.

Natural Gas

Year	Sources of Natural Gas	MBTU	Cost	% of Total Natural Gas
1999	PSCo	47,050	\$194,568	100%
2000	PSCo*	2,500	\$7,750	5%
	GSA/Tiger*	44,500	\$138,250	95%
	Total Energy*	47,000	\$146,000	100%

• Table 2 Natural Gas (FY 99)

* ALL DATA FOR THE 2000 FY ARE PROJECTED.

PSCo Electricity

As the table shows, the vast majority of NREL's electricity is purchased from PSCo (Public Service Company of Colorado). In 1999, the total electrical utility cost from PSCo came to \$906,451, of which almost 65% of the charges were for electrical demand. This percentage shows that NREL's electrical utility bill can be greatly reduced by reducing power usage at peak times. The table below shows electrical energy use broken down by site/leased space and by NREL owned/leased land. The table also shows that the majority of NREL's electrical power is used at the South Table Mountain permanent facilities. Consequently, any energy saving measures should be focused on reducing peak demand in NREL-owned facilities.

PSCo Electrical Energy Breakdown

Location	kWh	Cost	% of Total PSCo Electricity
STM	13,190,220	\$522,767	67.0%
NWTC	2,293,620	\$130,475	11.6%
Leased space			
Included in Building Lease	2,252,449	\$96,855	11.4%
Outside of Building Lease	1,955,280	\$156,354	9.9%
Total	19,691,569	\$906,451	100%
Total NREL Owned	15,483,840	\$653,242	72.1%
Leased Buildings	4,207,729	\$253,209	27.9%
Total	19,691,569	\$906,451	100%

• Table 3 PSCo Electrical Energy Breakdown (FY 99)

NREL Wind Energy from PSCo

Of the total purchased energy from PSCo, 0.3% is currently specified as wind energy. However, NREL has recently made a formal commitment to purchase nearly 1,200 blocks (100kWh each) per month of Windsorce green power from PSCo. This will represent about 10% of the electricity load of our permanent facilities. In addition, discussions are underway with PSCo to install a DOE-owned 750kW turbine in their planned 10MW expansion to the Ponnequin wind farm on the Colorado-Wyoming border. On completion

of both the Windsource buy and the turbine installation, NREL will receive 25-30% of its electricity as green power over the next three years¹.

NREL-Produced Energy

In addition to the energy purchased from PSCo, NREL produces 52,133 kWh of energy from PV's resulting in cost savings of \$2,513 per year. The cost savings of \$2,513 per year is based on the average electricity cost (\$0.0482/kWh) from PSCo and does **not** include set up or maintenance costs for the PV panels. Also, this cost savings averages the total savings from the PV and does not properly represent the demand load savings. Since PV's typically work their best during peak times, they save more money by reducing electrical demand charges.

Wind energy produced by NWTC was not included in Table 1. Currently, the amount of power generated by NWTC and the amount of power to the PSCo grid is unknown. At the time of this report, NWTC avoids costs from Public Service Company by supplying power up to what they are consuming when the wind blows and when they are generating electricity. Once energy production exceeds the loads at NWTC, the excess power is fed into the PSCo grid. Power production varies greatly from year to year depending on the wind season, experimentation schedules, etc. Metering for NWTC power production is being installed and Site Operations has been contacted to find a way to acquire this metered data. The turbines attached to the PSCo grid are capable of generating 900kW of power but generate power only when experiments are being performed. NREL is not compensated monetarily by PSCo for the energy it puts onto the power grid.

Natural Gas

Natural gas is used mainly to heat NREL facilities. Natural gas usage, like electricity, varies year to year. However, unlike electricity, natural gas use depends on weather conditions rather than on laboratory practices. In general, natural gas usage is greater during the winter months than summer months.

As of April 1, 2000, the SERF, FTLB Central Plant, and PDU have their gas supplied by GSA/Tiger for a cost savings of 20-30%. PSCo supplies the rest of the facility with natural gas. The table below summarizes the 1999 natural gas data as well as projects that the year 2000 should yield. Please note that the year 2000 data is an estimate.

¹ Information collected from the 'Greening of NREL' project lead by Sue Hock.

PSCO Natural Gas Energy Breakdown (1999)

Location	MMBTU	Cost	% of Total PSCO Natural Gas
STM	46,028	190,201	97.8%
NWTC	0	0	0%
Lease	1,022	4,367	2%
Total	47,050	194,568	100%

• Table 4 PSCO Energy Breakdown (FY 99)

Economics

Electricity

All electrical power purchased from PSCo (or any utility company) is broken down into a direct charge per Kilowatt hour and a demand charge.

Direct Energy Charges - NREL currently pays a direct charge of \$0.01612/kWh. This is a flat rate and does not change anytime during the year. Also, NREL pays a flat meter charge of \$125.00 for electrical service each month.

Demand Charges - Two demand charges are made to NREL's electricity bill, an On-peak Demand Charge and an Off-peak Demand Charge.

On-peak Demand Charges - these charges are based on NREL's power use during times of the day where the utility company sees the largest power demand. On-peak hours are typically workday hours (7 a.m.-6 p.m.). During this time, PSCo takes the top 15 minutes of power use for each month and applies the demand charge.

Off-peak Demand Charges - these charges are based on NREL's power use during off-hour times where the utility company sees the largest power demand. Off-peak hours are typically non-work or nighttime hours (7 pm-6 am). During this time PSCo takes the top fifteen minutes of power use for each month and applies the demand charge.

Consequently, 65% of our electrical bill is based on 30 minutes of energy use (On-peak and Off-peak time) each month when our electricity use is the greatest.

Natural Gas

As of April 1, 2000, the majority of our natural gas is purchased from GSA/Tiger at a rate of about \$3.50 per MMBTU. Previously, NREL purchased all of its natural gas from PSCo at a rate of \$4.44 per MMBTU. Gas prices, unlike electricity prices, depend on availability as well as demand. In the winter, gas prices increase due to larger heating demands. In general, the price of gas is unpredictable. Consequently, to reduce the amount of money spent on natural gas, you must simply reduce the amount of gas purchased.

In addition to the charge per MMBTU mentioned above, there are a number of add-on charges associated with natural gas use. These fees include service fees, transportation fees, etc.

Recommendations/Suggestions

- **Make individual departments responsible for paying their own utility bills.** Currently, individual departments have no reason to be concerned about their power consumption. Power for each department is essentially “free,” resulting in no real reason to try to conserve or reduce power use. By making each department responsible for its energy use, you increase awareness and force people to think about how they use power in their everyday activities.
- **Install more photovoltaic arrays.** Photovoltaics (PV) work their best when electrical energy demand is the highest. Therefore, PV panels could reduce our peak load resulting in substantial cost savings. Consequently, the PV's would end up paying for themselves in a short time period due to the high electrical demand charges NREL currently endures. One good place to install PVs would be on a parking cover structure. The structure would shade vehicles as well as the asphalt in the parking lot reducing the “heat island effect” (see Color of Roofing and Paved Surfaces section) and could be used to generate electricity.
- **Collect more energy from NWTC site.** Collect power from the wind turbines at the NWTC on evenings, weekends, and holidays when no tests are being run. Also, keep older turbines, which are not being tested, operational for power production. In the future, NWTC could allow some of its older turbines to create power continuously for NREL use.
- **Education programs for the NREL populace.** Increase energy awareness in NREL employees through educational seminars. These seminars should stress conservation of energy in the workplace as well as at home.
- **Biomass energy produced at NREL.** Currently, biomass technologies are not used to generate power for NREL. In the future, NREL may use the field test laboratories thermochemical user facility to generate up to 30 kilowatts from biomass.
- **Solar hot water.** No evidence of solar hot water use was found at the Lab. Solar water heating generally has a very rapid payback, and its use at NREL should be investigated.
- **Electrical demand reduction.** Records of electrical energy consumption including demand charges should be routinely kept and graphed. This should be done by building or by center to determine where peak electrical use could be minimized.
- **Support Windsource purchases by NREL staff for personal use.** NREL staff should be made aware of the availability of Windsource energy for home use, its benefits to the environment, its costs, etc.

Site Open Space

Current Space Use and Locations

NREL operates at five facilities located in Golden, Colorado; one facility located 20 miles north of Golden in Boulder, Colorado; and one facility located in Washington, D.C. The Colorado-area locations include the DOE-owned South Table Mountain (STM) and National Wind Technology Center (NWTC) as well as leased facilities in the Denver West Office Park (DWOP), the Joyce Street Facility (JSF), and the 48th Street Facility (48th). The table below summarizes the building space occupied by NREL.

NREL Occupied Space	Building Area in Net Square Feet
DOE-owned	277,532
Leased Space	255,333
Total Building Space Occupied by NREL	532,865

• Table 5 NREL Occupied Space

Open Space by Site

NREL's largest site is the DOE-owned South Table Mountain. This site is 352 acres (15,333,181 ft²) in size. Of this space, nine buildings that house research and support staff cover 239,482 ft² (1.6% of land). The rest of the land is covered by natural habitat and plant life.

The other DOE-owned site is the National Wind Technology Center (NWTC). The NWTC site is 280 acres (12,196,849 ft²) in size. Most of its 38,050 ft² (0.3% of land) of building area is used for research and support in three primary buildings. The rest of the land is used for testing numerous wind turbine technologies and is left mostly to the natural habitat and plant life.

NREL's remaining building space (255,333 ft²) is leased and houses administrative and support functions ². The Denver West Office Park holds about 60% of NREL's 1,040 (peak) person workforce. The Joyce Street Facility (56,000 ft²), the 48th Street Facility (4,572 ft²), and the Washington, D.C., office (6,447 ft²) comprise the other leased facilities. Table 6 below summarizes these statistics.

² Information from the Site Development Plan for NREL (September 1999). Page 1.

Site Name	Area (Acres)	Total Net Square Feet of Buildings	Status	Distance from STM Site
South Table Mountain	325	261,974	Owned	--
National Wind Technology Center	280	38,080	Owned	20.0
Denver West Office Park	N/A	191,786	Leased	1.2
Joyce Street Facility	N/A	56,000	Leased	8.0
48 th Street Facility	N/A	4,752	Leased	6.0
Washington, D.C.	N/A	6,447	Leased	--

• Table 6 Building Area Use (as of July 1999)

Of the land owned by NREL only about 135 acres at the South Table Mountain Site are developable (about 40% of the land at that site)³.

Recommendations/Suggestions

Follow the LEED Green Building Rating System recommendations for site selection and use. Applicable LEED codes are as follows:

- Site Credit 5: Reduce the development footprint (including building, access roads, and parking) to exceed the local zoning's open space requirement for the site by 25%.
- Site Credit 1: Do not develop buildings on portions of sites that meet any one of the following criteria:
 - Prime agricultural land as defined by the Farmland Trust.
 - Land that has an elevation lower than 5 feet above the elevation of the 100-year flood (as defined by FEMA).
 - Land subject to landslides, coastal erosion, or wildfire.
 - Land that provides habitat for any species on the federal or state threatened or endangered list.
 - Any wetland as defined by 40 CFR, Parts 230-233 and Part 22.
 - Land that prior to acquisition for the project was public parkland, unless land of equal or greater value as parkland is accepted in trade by the owner of the public land.

³ Information from the Site Development Plan for NREL (September 1999). Page 3.

Site Parking and Roadways

Current NREL parking areas and paved roads cover 3.1% of all NREL-owned land. Dirt roads cover 1.2% of all NREL-owned land. Table 7 below summarizes NREL land use for parking and roadways:

Site	Square Feet	% of Total NREL Land
STM		
Paved Roadways	315,450	1.1%
Paved Parking Lots	262,925	1.0%
Dirt Roadways	33,750	0.1%
NWTC		
Paved Roadways	139,000	0.5%
Paved Parking Lots	141,875	0.5%
Dirt Roadways	296,060	1.1%
Total Land Covered by Paved Roadways and Parking	859,250	3.1%
Total Land Covered by Dirt Roadways	329,810	1.2%
Total Land Covered by Roadways and Parking	1,189,060	4.3%

• Table 7 Parking and Roadways

Recommendations/Suggestions

- **Paint the roadways light albedo colors.** When installing new roadways or during roadway repair, color roadways with a reflective color to reduce “heat island” effects (see the Color of Roofing and Paved Surfaces section).
- **Construct parking lots out of pervious materials.** Pervious materials allow water to percolate into the ground rather than contribute to storm-water drainage loads.
- **Alternative Vehicles.** Encourage increased use of mass or human-powered transportation.

Building Density

As of September 1999, NREL employed 955 people with a total peak headcount in FY 1999 of 1050. The table below summarizes the building population density as determined in July 1999. For a more detailed breakdown of building density by individual building, please see Table 2 in the September 1999 Site Development Plan located in the appendices.

Building Name	Gross Sq. Ft.	Office Space	Number of Occupants/ Workstations	Office Space Sq.Ft. / Person	Status
South Table Mountain	299051	58226	327/353	165	Owned
National Wind Technology Center	43760	16016	97/112	143	Owned
Denver West Office Park	258806	106584	531/590	181	Leased
Total	601617	180826	955/1055	171	—

• Table 8 Building Density Data

Recommendations/Suggestions

- **Telecommuting to work.** Telecommuting has many advantages, including reduced requirements for office space.
- **Swing shifts.** Flexibility in work schedules could allow for more than one individual per cubicle. Alternative work schedules and swing shifts (ex. second shift and third shift) should be investigated.

Tree Planting

NREL has no current standard on tree planting or tending.

Recommendations/Suggestions

- **Follow the LEED Green Buildings Rating System when planting new trees.** The LEED System recommends the following:
 - **Site Credit 7:** Provide shade (within 5 years) on at least 30% of non-roof impervious surface on the site, including parking lots, walkways, plazas, etc., OR, use light-colored/high-albedo materials (reflectance of at least 0.3) for 30% of the site's non-roof impervious surfaces, OR place a minimum of 50% of parking space underground, OR use open-grid pavement system for a minimum of 50% of the parking lot area.
 - **Site Credit 5:** On greenfield sites, limit site disturbance including earthwork and clearing of vegetation to 40 feet beyond the building, primary roadway curbs, and main utility branch trenches; OR, on previously developed sites, restore a minimum of 50% of the remaining open area by restoring the health of the soil and planting native or adapted vegetation.
- **Grey-water could be used to water any trees planted at NREL.** Runoff from buildings, parking lots, and roadways could be collected and reused to water trees.

Color of Roofing and Paved Surfaces

Roofing

Roofing materials are either asphalt tar with gravel or a black rubber membrane, except where the roof is used to reflect light into a daylight area. Roofs near daylight areas are white.

Lawrence Berkley National Laboratory's Energy and Environment Division has been making a case for years that painting buildings black in sunny climates burns energy. The heat captured by roofs, roads, and other black or dark materials are a major contributing factor to why cities average five degrees warmer than surrounding rural communities during summer.

The warmer temperatures in these so-called "heat islands" translate into an extra \$4 billion in cooling costs in the United States each year, studies estimate. They are also an indirect contributor to air pollution, since warmer temperatures boost chemical reactions that produce smog.

Now the heat island problem has also been taken up by President Clinton. Much of the cool communities approach that began at LBL--which seeks to decrease temperatures in heat islands with reflective roofs, lighter pavement, and shade trees--has been integrated into Clinton's Climate Change Action Plan (CCAP). The comprehensive plan seeks to cut the nation's energy use 10 percent by the year 2000 with about a dozen energy-saving strategies, including cool communities measures⁴.

Paved Surfaces

Currently no attempt is made at reducing the heat absorption of NREL parking lots or other paved surfaces. Information from the LBNL Heat Island Group suggests that the reflectance (albedo) of paved surfaces range from 0.05 to 0.16, with an average rating of 0.12. These reflectance numbers show that most of the light that falls on paved surfaces is turned directly into heat. For more information about the benefits of reflective paved surfaces, please visit Lawrence Berkeley's National Laboratory Cool Roof homepage mentioned above.

Recommendations/Suggestions

- When buying roofing materials, look for the energy star® label. Numerous companies now sell energy star® labeled roofing materials.

⁴ LBL Energy and Environment Division Web Page on Heat Islands <http://eetd.lbl.gov/HeatIsland/CoolRoofs/>

Habitat/Site Preservation

NREL's basic philosophy regarding vegetation is to preserve and protect the ecosystems on the site in their natural state as much as possible. There is some landscaping using non-native drought-tolerant species adjacent to some of the buildings and even a few areas at the STM site of sodden bluegrass. However, the native vegetation and natural character of the landscape is maintained over the majority of the site. Revegetation of areas to be left in their natural state following disturbance from construction or other outdoor activities is conducted using a native seed mix of grasses and forbs. This mix is comprised predominantly of natives that were originally present on the site before disturbance. The use of native species is strongly encouraged at both the STM and NWTC sites whenever feasible.⁵

Baseline Data and Information

Please refer to the National Renewable Energy Laboratory Environmental Report for 1999 for baseline data and information. This report goes into detail about current site characteristics including geology, soils, hydrogeology, vegetation, wildlife, endangered species, and natural resource issues. This report also covers ground-water and storm-water protection. All current 1999 activities are given in detail in this report.

Landscaping

Minimal landscaping is performed at the STM or NWTC sites, however, the leased buildings in the Denver West complex are landscaped extensively. Mowing is performed around roadways and buildings for fire protection. After building construction, the land is seeded with natural vegetation. Very little water is used for landscaping purposes. For more information regarding NREL's landscaping practices, see the 1999 Environmental Report.

Weed/Pest Control

Some herbicide and biological controls are used to reduce weeds. These methods are used in conjunction with other weed control methods including: mowing, reclamation of disturbed areas, and prevention techniques (e.g. obtaining certified weed-free mulch and limiting driving of vehicles off established roadways). These strategies have been successful in significantly reducing populations of diffuse knapweed and Canada thistle on the sites.

Recommendations/Suggestions

- **Collect baseline data on herbicide, pesticide, and water use.** No data is collected for these topics. It is believed that presently the use of herbicides, pesticides, and landscaping watering are already at a minimum level. Natural landscaping requires no maintenance and consequently, is cost effective.

⁵ NREL Environmental Report - 1999. Page 31.

Cultural Resource Preservation

Three historic and cultural resources were identified as significant cultural resources that should be preserved. These sites include an open-air amphitheater, a stone bridge spanning a natural drainage channel adjacent to the amphitheater, and a stone and concrete ammunition bunker below the amphitheater site. NREL has had these sites added to the National Register of Historic Places. For more information, please see the 1999 Environmental Report.

Individual Building Energy Use

Building Energy Use

Only the buildings at the South Table Mountain site and National Wind Technology Center are owned by NREL, all other buildings are leased. Since leased buildings cannot be modified, those buildings have not been audited for energy saving features. All energy-efficient improvements allowed under our leasing contracts have been accomplished in these leased buildings.

All NREL-owned buildings went through an energy audit in 1997 and are, in general, energy efficient. An energy audit update has been completed for the Sustainable NREL project. The energy audit executive summary is included in the appendix to this report. The energy audit summarizes the major changes to be made to each of the buildings and lists the relative costs and payback periods (in years) of each suggested improvement. For a copy of the complete energy audit, see Otto Van Geet.

Design Goals and Standards for New Building Construction or Existing Building Renovation

NREL has its own set of design criteria and specifications that are unique compared to any other government laboratory or facility. These standards are created in-house and updated periodically. These standards are based on the Federal Code of Regulations as well as Executive Directives issued by the president. For more information or to see the current building design criteria and specifications, contact Mike Glaser.

The best way to evaluate energy-conservation measures for a building is to first create a model of that building using a computer simulation program. Once the model is complete, changes can be made to that model to see what the effects would be if that change were implemented. For each new building or renovation performed by NREL, a DOE-2 model is created for the building. The Department of Energy (DOE) produced the DOE-2 software, an hourly simulation program that is highly accepted with the buildings industry.

According to Mr. Glaser, all new construction done at the NREL site exceeds the Federal Code of Regulations for building energy use (10CFR435) by 30 to 40%.

Process Loads

Process loads, as defined by NREL site operations, are the equipment loads tied to HVAC equipment (as opposed to HVAC loads). These loads include pumps, motors, air compressors, vacuum pumps, etc. These loads are unavoidable but can be minimized in two ways: 1) Optimize the use of equipment so that it is only on when needed. 2) Purchase energy-efficient equipment.

Currently, there are no policies limiting process loads. However, Site Operations controls some process loads through a central computer system. The current computer system is very old and outdated. NREL is currently trying to acquire money to update this computer system. The newer control system NREL is hoping to purchase will allow the user to optimize all process loads on campus. This will result in large energy and cost savings.

Recommendations/Suggestions

- **Find energy-efficient replacement equipment for both renovation and new building construction.** Initial costs of energy-efficient equipment are usually slightly higher than conventional equipment, but a life-cycle cost analysis will reveal economic savings over the life of the product.
- **Collect baseline data on equipment loads.** Much of the equipment on site is oversized for the application. Oversized equipment draws more power than optimized equipment. Example: Analyze circulation and other fluid pumping requirements to optimize pump energy efficiency.

Building Equipment Loads

Currently there is no policy or procedure that limits building equipment loads.

LABORATORY EQUIPMENT LOADS - Due to the type of work done at NREL, it is nearly impossible to limit or schedule lab work in any way to save energy or reduce peak electrical loading. The research is the product and the driving force at NREL.

OFFICE EQUIPMENT LOADS - Office loads that use electricity should be replaced with energy star® equipment when possible. Some of the equipment that could be replaced includes the following: computers, copiers, printers, fax machines, coffee pots, refrigerators, microwaves, etc. The EPA is constantly updating the types of equipment that meet the energy star® requirement. Consequently, the best way to determine what products are energy star® compliant is to either call the energy star® hotline (1-888-STAR-YES) or visit their Web site at www.energystar.gov.

More information on office equipment loads and the energy star® program is presented in the appendix under "Office Equipment Loads."

Recommendations

- **Eliminate some vending machines.** Each pop machine draws 8.9 kWh each day. The energy star® program is currently investigating vending machines, water coolers, as well as many commonly used motors. Once these findings are released, energy star® labeled products should be obtained.
- **Eliminate redundant kitchen supplies.** Many NREL employees bring in their own coffeemakers, microwaves, toasters, refrigerators, etc. for their own personal use. NREL already provides these appliances in designated break areas.
- **Eliminate bottled water coolers with heater elements.** Some water coolers have heater coils within them and constantly draw power to keep hot water ready for use.
- **Eliminate multiple printers, scanners, and computers.** Some NREL employees possess their own printers, scanners, and/or multiple computers. Network capabilities at NREL could easily support more public office equipment as necessary.
- **Collect baseline data on current Energy Star equipment use.** No data has been collected on the percentage of equipment loads meeting energy star® requirements.
- **Employ timing circuits in all buildings where appropriate.** Timing circuits can be used to eliminate most equipment loads during nights and weekends. Equipment such as pop machines and water coolers should be added to a timing circuit to turn them off.

Lighting

Lighting conditions in each building were studied during the individual building energy audits. Current lighting is very energy efficient and daylighting is used wherever possible. Additionally, in many areas that are day-lit, light levels are monitored with light sensors. The light sensors turn on lighting as the light levels drop below allowable working levels. In areas where daylighting isn't a viable option, motion sensors have been added. To maintain and improve lighting efficiency, it is recommended that a building energy audit file be kept up-to-date.

Motors

By design standard, any motors purchased by NREL for process loads must be high-efficiency motors. Motors purchased for experiments are not regulated by this design standard.

Alternate Refrigerants

Current design standards require the purchasing of alternate refrigerants. CFC, HCFC, and Halon are not allowed in any new equipment or new materials. All new refrigeration equipment is specified to use non-ozone-depleting refrigerants. However, many building cooling systems use HCFC (R-22), but all R-22 will be banned from use by 2010.

Transportation

NREL As A Model For An Advanced Transportation Community

NREL supports alternative transportation in several ways:

- **Free RTD EcoPasses:** As of July 17, 1997, NREL employees receive an EcoPass as part of their benefits package. The EcoPass permits the cardholder free RTD transportation (non-transferable) anywhere in the Denver metro area where RTD services. This includes, among other destinations, SkyRide to the airport, Boulder, Nederland, etc. Note that EcoPass cannot be used for RockiesRide and other special sporting event buses. The table below summarizes usage of the EcoPass by NREL employees for traveling to DIA and downtown meetings.

YEAR	MILEAGE SAVED	MILEAGE FUNDS SAVED	PARKING FUNDS SAVED
FY 98	12,318 miles	\$4003.57	\$6724.08
FY 99	16,714 miles	\$5330.82	\$13,385.00
FY 00 (as of 5/31)	7,705 miles	\$2388.55	\$6756.00

• Table 9 NREL EcoPass Data

- Currently NREL has no formal policy on telecommuting to work although a small number of employees are telecommuting with managerial consent. The option of telecommuting to work is viable and realistic for a laboratory environment where many work-related papers, documentation, etc. could be accomplished at home. The benefits of telecommuting to work are numerous and go beyond the simple scope of reduced vehicle emissions. Telecommuting reduces the number of employee sick days, increases employee morale, lowers building space and electrical demand on site, etc. Telecommuting to work should be made an option for NREL staff. For more information on this subject and how NREL could use telecommuting in the future, please contact the following individuals on the Staff Council Telework Committee: Trudy Forsyth, Mary Colvin, Jeff Dominick, Randy Ellingson, Kelly Ibsen, and David Kline.
- NREL maintains a shuttle service between buildings on the STM and Denver West sites. This shuttle service is run with alternative-fuel vehicles, and is currently performed on demand (you call a number and tell the driver where you are and where you're going).
- NREL has limited teleconferencing and video facilities available for staff use.
- Each of the larger NREL buildings on the South Table Mountain site and Denver West site have bicycles to check out for travel between buildings.
- The SERF building has men's and women's locker rooms equipped with showers that may be used by bicyclists.

Commuting To Work

In June 2000, a survey was completed to determine the commuting habits of the NREL populace. Four-hundred-twenty-three NREL employees responded to this survey. At that time, NREL employees used the following means to get to and from work each day.

Transportation Type	Responses	% of NREL Population
Personal Vehicle	339	80%
Bus	27	6%
Carpool	23	5%
Bike	17	4%
Metro	9	2%
Walk	5	1%
Other	3	1%

• Table 10 Commuting Transportation Types

This table reflects the primary type of transportation for each employee. Many employees listed a number of different methods of transportation. These numbers reflect only those employees who responded to the survey.

VEHICLE STATISTICS

PERSONAL VEHICLE STATISTICS	
Number of people	339 people
Number of people who drive infrequently	13 people
Number of people who took the bus infrequently (of personal vehicle drivers)	9 people
Longest distance traveled to work (round trip)	175 miles
Shortest distance traveled to work (round trip)	1 mile
Average distance traveled to work (round trip)	29.2 miles
Total miles driven by NREL employees to work (per year)	2,761,123 miles/year
Average miles per gallon of NREL employees vehicles	25 miles per gallon
Average emissions produced per vehicle per year	215 lbs. of CO 31 lbs. of NOx 27 lbs. of VHC 17 lbs. of Pm10 8,462 lbs. of CO ₂
Total emissions produced by NREL personal vehicles per year	75,726 lbs. of CO 11,018 lbs. of NOx 9,496 lbs. of VHC 6,148 lbs. of Pm10 2,978,485 lbs. of CO ₂
BUS STATISTICS	
Number of people	27 people
Number of people who used the bus infrequently	15 people
Longest distance traveled to work (round trip)	100 miles
Shortest distance traveled to work (round trip)	3 miles
Average distance traveled to work (roundtrip)	45.7 miles

CARPOOL STATISTICS	
Number of people	23 people
Number of people who carpool infrequently	8 people
Longest distance traveled to work (round trip)	150 miles
Shortest distance traveled to work (round trip)	7 miles
Average distance traveled to work (round trip)	56.3 miles
BIKE TRAVEL STATISTICS	
Number of people	17 people
Number of people who bike infrequently	18 people
Longest distance traveled to work (round trip)	20 miles
Shortest distance traveled to work (round trip)	4 miles
Average distance traveled to work (round trip)	10.2 miles
METRO TRAVEL STATISTICS	
Number of people	9 people
Longest distance traveled to work (round trip)	40 miles
Shortest distance traveled to work (round trip)	2 miles
Average distance traveled to work (round trip)	17.1 miles
PEDESTRIAN TRAVEL STATISTICS	
Number of people	5 people
Longest distance traveled to work (round trip)	5 miles
Shortest distance traveled to work (round trip)	0.75 miles
Average distance traveled to work (round trip)	2.5 miles

• Table 11 Vehicle Statistics

AVERAGE AND TOTAL EMISSIONS NUMBERS BASED ON COLORADO DEPARTMENT OF HEALTH STATISTICS FOR 1999 VEHICLE AVERAGE EMISSIONS. THESE NUMBERS INCLUDE ALL PERSONAL VEHICLE TRAVEL REPORTED ON THE JUNE 2000 SURVEY. ABBREVIATIONS: CO = CARBON MONOXIDE, NOX = NITROUS OXIDES, VHC = VOLATILE HYDROCARBONS, PM10 = PARTICULATE MATTER SMALLER THAN 10 MICRONS IN SIZE, CO2 = CARBON DIOXIDE.

The average emissions generated by each NREL employee traveling to and from work can be used to determine vehicle emissions avoided each year. The table below displays these average emissions avoided by NREL employees using alternative modes of transportation:

ALTERNATIVE TRANSPORTATION TYPE	YEARLY VEHICLE EMISSIONS AVOIDED
Bus (27 people)	5,805 lbs. of CO 837 lbs. of NOx 729 lbs. of VHC 459 lbs. of Pm10 228,474 lbs. of CO2
Metro (9 people)	1,935 lbs. of CO 279 lbs. of NOx 243 lbs. of VHC 153 lbs. of Pm10 76,158 lbs. of CO2
Carpool (half of 23 people)	2,473 lbs. of CO 357 lbs. of NOx 310 lbs. of VHC 196 lbs. of Pm10 97,313 lbs. of CO2
Bike (17 people)	3,655 lbs. of CO 527 lbs. of NOx 459 lbs. of VHC 289 lbs. of Pm10 143,854 lbs. of CO2
Walk (5 people)	1,075 lbs. of CO 155 lbs. of NOx 135 lbs. of VHC 85 lbs. of Pm10 42,310 lbs. of CO2
TOTAL EMISSIONS AVOIDED	14,943 lbs. of CO 2,155 lbs. of NOx 1,877 lbs. of VHC 1,182 lbs. of Pm10 588,109 lbs. of CO2

• Table 12 Avoided Emissions

The emissions values stated above are based on average NREL emissions per employee. These numbers are based on ONLY those employees who stated they use an alternate form of transportation on a regular basis. The values above also don't reflect bus emissions. Currently RTD buses are only tested for opacity and not for emissions.

NREL Bus Use (RTD)

Would you use RTD if it were more convenient?

Response Type	Number of People
N/A	66
NO	124
YES	261

Do you use RTD for downtown meetings, conferences, or seminars?

Response Type	Number of People
Did not answer	75
NO	281
YES	66

Of those people who responded that they use RTD for downtown meetings, the following data was collected:

	Times used per Year
TOTAL	178
MAX	20
MIN	1
AVERAGE	2.8

NREL Shuttle Service

Do you use NREL shuttle service?

Response Type	Number of People
Did not answer	135
NO	155
YES	132

Of those people who responded that they use the NREL Shuttle Service, the following data was collected:

	Times used per Month
TOTAL	885
MAX	40
MIN	1
AVERAGE	5.9

NREL employees were also polled about their travel between buildings in personal vehicles. The following data was collected:

Type	Value	Units
Distance Traveled	1,913	Miles per Month
Distance Traveled	22,960	Miles per Year
Gas Used	918	Gallons per Year
Emissions produced Traveling between Buildings	CO 630	Pounds per Year
	NOx 92	
	VHC 79	
	Pm10 51	
	CO2 20,204	

• Table 13 Between Building Personal Vehicle Use

NREL employees also use their cars for personal business and lunchtime travel. The following table summarizes the survey results for personal business and lunchtime travel:

Type	Value	Units
Total Distance Traveled	203,664	Miles per Year
Max Distance	6,480	Miles per Year
Min Distance	0	Miles per Year
Average Distance	521	Miles per Year
Total Emissions Produced	CO 5,586	Pounds per Year
	NOx 813	
	VHC 700	
	Pm10 454	
	CO2 4,480,608	

• Table 14 Personal Business and Lunchtime Travel

Finally, any unreported business travel was also included in the survey. The following table summarizes the survey results for unreported personal vehicle use for business:

Type	Value	Units
Total Distance Traveled	34,788	Miles per Year
Max Distance	2,400	Miles per Year
Min Distance	0	Miles per Year
Average Distance	102	Miles per Year
Total Emissions Produced	CO 954	Pounds per Year
	NOx 139	
	VHC 120	
	Pm10 78	
	CO2 765,336	

• Table 15 Unreported Business Travel

Commuting Data Assumption

No attempt to extrapolate this data for the entire NREL population was made based on the assumption that the people who do care about emissions and greenhouse effects would be more prone to respond to such a survey.

NREL Vehicle Fleet

NREL Fleet Vehicle data is summarized in the table below. This information was obtained from the FY 99 GSA report.

Fuel Type	Number of Vehicles	Equivalent Gallons of Gasoline Used
Diesel	3	720 gallons
E-85 (ethanol)	2	100 gallons
Gasoline	34	16,100 gallons
Natural Gas	9	1,620 gallons
Totals	48	18,540 gallons

• Table 16 NREL Fleet Vehicle Data

Complete mileage data was available for 44 or the 48 NREL fleet vehicles for January through May 2000. During that time, the average miles traveled per vehicle was 2,157. If these numbers are projected for all 48 vehicles for an entire year, then the NREL fleet travels a total of 248,486 miles/year. Using the "equivalent gallons" figures above, this implies that the average fuel economy rating for the NREL fleet is 13.4 mpg, assuming that the miles traveled do not vary significantly from one year to the next. Currently, then, the NREL fleet produces the following emissions each year:

Pollutant	Amount produced per year
Carbon Monoxide (CO)	6869 lbs.
Nitrous Oxide (NO)	1000 lbs.
Vol. Hydrocarbons (VHC)	863 lbs.
Pm 10 (less than 10 microns)	559 lbs.
Carbon Dioxide	363384 lbs.

• Table 17 NREL Fleet Vehicle Emissions

NREL also uses many DOE-owned research vehicles for various transportation services. The actual number of these vehicles fluctuates throughout the year. These vehicles are here primarily for testing and research purposes. Data is not available for these vehicles. (Examples: two hybrid gas/electric cars stationed at TTF, Ford F-550's at NWTC, etc.)

NREL Business Travel

The table below summarizes airline travel miles and total travel costs incurred by NREL employees in FY99. The airline total trip miles shown represents "market trip miles" and includes only the "as-the-crow-flies" miles between the trip origin and destination.

TRIP COUNT	TRIP DAYS	TRIP MILES	AIR COST	HOTEL COST	CAR COST	TOTAL COST
3,773	15,525	10,121,219	\$2,434,661	\$277,537	\$120,788	\$2,832,986

• Table 18 NREL Business Travel

Transportation Recommendations and Suggestions

Remove the stop signs on Denver West Parkway that are located between the FTLB and the OTF. During a typical workday, between the hours of 7 a.m. and 6 p.m., 468 vehicles were observed traveling in an east or west direction at these stop signs. During this time, only 61 vehicles were observed travelling in a southerly direction on the intersecting access road. Most vehicles do not stop at these signs and this is probably creating a more serious safety situation than existed before the signs were installed.

Less than 10% of the vehicles moving on Denver West Parkway stopped completely. Roughly, 10% did not even slow down for the signs, and the remainder slowed in varying degrees. It should be noted that these observations were performed in hourly increments on several succeeding days to account for any timing irregularities.

In a study done at North Carolina State University (www4.ncsu.edu/~frey/emissions/), the emission levels of various pollutants were monitored for a vehicle traveling on a typical 10-mile commute in a urban setting. To summarize the outcome of the study, vehicle accelerations account for the majority of emissions during the trip. Although the acceleration portion of the trip accounted for only 18% of the distance traveled and 36% of fuel use, over half the total nitrous oxide (NO) and carbon monoxide (CO) emissions were attributable to acceleration. Additionally, 40% of the total hydrocarbon emissions were associated with acceleration and approximately 35% of the CO₂ were ejected during acceleration. If vehicles travelling east or west were allowed to cruise through the intersection, then emissions generated would be reduced to an insignificant level compared to the present situation.

Many exciting suggestions for sustainable transportation improvements grew out of a meeting of some NREL staff on January 21, 2000. Some of the more practical and palatable ideas are:

- **Ensure that flexible fuel vehicles are using mostly alternative fuels.** Some of the alternate fuel vehicles are being run only on gasoline. This defeats the purpose of buying flex-fuel vehicles.
- **User-friendly pedestrian walkways should exist between buildings.** There are currently a few walkways between buildings, but more should be built to encourage walking between buildings.
- **Become a field test site for any alternate fuel vehicles.** More types of alternate fuel vehicles should be tested here at NREL.
- **Develop incentives for staff to purchase alternative fuel vehicles (interest free loans, etc.).**
- **Work with RTD to get bus routing more convenient for NREL employees (see survey results).**
- **Convert entire NREL fleet to renewable fuels.** Many of the maintenance vehicles NREL uses are heavy-duty trucks. Many of these trucks could be replaced with smaller golf cart-type maintenance vehicles.

- **Use electric vehicles on site when reasonable and feasible.** NREL has two electric charging stations on site but currently no EVs. Some electric vehicles are on order from GSA but have not arrived.
- **Provide incentives for carpooling.**
- **Reduce air travel (replace with improved communications).** Use video teleconferencing technology whenever appropriate. This would also save NREL the costs of plane tickets, hotels, car rentals, etc.
- **Build an on-site, nonprofit cafeteria serving healthy foods (this could help justify the removal of some of the vending equipment on campus).**
- **Eliminate reimbursement for mileage to and from DIA and related parking charges to encourage RTD use.**
- **Work with GSA in selecting smaller, fuel-efficient vehicles for fleet use where appropriate.**
- **Establish a reward/incentive program for EcoPass use.**

Total CO₂ Produced by NREL Activities

Total CO₂ generated is a reasonably accurate characterization of NREL's annual environmental footprint. The table below summarizes CO₂ generation by all NREL activities.

NREL ACTIVITY	DATA OBTAINED FROM	POUNDS OF CO ₂ PRODUCED IN BASELINE YEAR
Commute:Personal Vehicle *	Trans Survey (6/00)	4,409,465
RTD (Eco-pass) **	Trans Survey (6/00)	78,521
Carpool	Trans Survey (6/00)	232,650
Person. Veh. On campus travel	Trans Survey (6/00)	40,910
Lunch, Personal business travel	Trans Survey (6/00)	362,892
Unreported NREL business travel	Trans Survey (6/00)	61,985
Reported NREL business travel	FY 99	54,880
EcoPass (DIA downtown)***	FY 99	7,488
Airline Travel ****	FY 99	5,338,943
Out-of-town travel (taxi, rental,etc)	---	Data not available
NREL fleet vehicles	1-5/2000 (projected)	363,384
NREL research veh. (DOE-owned)	---	Data not available
Small engine use (see notes)	FY 99	7,372
Non-green electricity purchased	FY 99	39,306,781
Natural gas purchased	FY 99	5,508,614
Other *****	--	-0-
TOTAL CO ₂ GENERATED	--	55,773,885

• Table 19 Total CO₂ Produced by NREL

* NUMBERS SHOWN ARE PROJECTED OVER THE ENTIRE NREL POPULATION (955 EMPLOYEES IN FY 99 IN COLORADO LOCATIONS ONLY)

** FOR BUS/METRO, 200 PASS MILES/GALLON DIESEL IS THE FUEL USE FACTOR USED FOR PEAK COMMUTE HOURS PER CONSULTATION WITH RTD

*** ECO-PASS USE FOR DIA, ETC. TYPE TRAVEL REQUIRED THE USE OF THE RTD DAILY AVERAGE FUEL USE FACTOR, WHICH IS APPROXIMATELY 50-PASS MILES/ GALLON DIESEL PER BEST ESTIMATES IN CONSULTATION WITH RTD. PASSENGER MILES ARE NOT RECORDED BY RTD.

**** RESEARCH SHOWED AN INDUSTRY-WIDE AVERAGE OF 40-PASSENGER MILES/GALLON JET FUEL

***** "OTHER" COULD INCLUDE THE CO₂ PRODUCED BY CERTAIN TYPES OF CHEMICAL REACTIONS, INDUSTRIAL PROCESSES CONDUCTED BY NREL, OR EVEN THAT PRODUCED IN THE MANUFACTURE OF CONSTRUCTION MATERIALS. MOST YEARS THIS CONTRIBUTION WOULD BE EXTREMELY SMALL AND IMPOSSIBLE TO CALCULATE – HENCE, THE ZERO FIGURE IS RECORDED.

NOTES:

1) DOE EMISSIONS FACTORS USED IN THE ABOVE TABLE ARE: (IN LBS. OF CO₂/ GALLON OF FUEL)

MOTOR GASOLINE – 19.6

DIESEL FUEL – 22.4

JET FUEL – 21.1

NATURAL GAS – 117.08 LBS. CO₂ PER MILLION BTU

ELECTRICITY – 2.001 LBS. CO₂ PER KWH, ADJUSTED FACTOR FOR COLORADO

2) IT SHOULD BE NOTED THAT SMALL-ENGINE USE GENERATES 100 TO 1,000 TIMES MORE POLLUTANTS (CO, VHC, NO, NO₂, ETC.) PER UNIT TIME THAN AN AUTOMOBILE ENGINE. THE ORDER OF MAGNITUDE VARIATION IN EMISSIONS IS ATTRIBUTABLE TO DIFFERENT ENGINE TYPES, STATE OF TUNE, FUEL TYPES, ETC. NREL HAS REDUCED SMALL-ENGINE FUEL USE IN FY 00 BY APPROX. TWO-THIRDS. (A WORK CONTROL INITIATIVE IN REDUCING THE TOTAL LAWN AREA MOWED TO THE ABSOLUTE MINIMUM).

3) "DATA NOT AVAILABLE" IMPLIES THAT NO RECORDS ARE KEPT AND NO REASONABLE ACCURATE ESTIMATE COULD BE ASCERTAINED.

4) FOR ANY PERSONAL VEHICLE USE, A 25 MPG AVERAGE FUEL CONSUMPTION IS ASSUMED

Materials Use

Re-use/Recycle of Materials

Non-Construction Materials

Representative NREL buildings were used during a physical inventory of NREL-generated garbage. This task was completed to baseline current NREL waste/recycle practices. During this physical inventory, the total amount of waste and the amount of recycled materials in the waste stream were measured by weight.

To determine the best buildings to use as representative buildings, a walk-through survey of all NREL buildings was performed. During these surveys, current waste-handling practices were recorded. Following the survey, the team consulted many NREL employees from ES&H as well as Waste Management. Finally, it was decided that Building 17 and SERF would be the representative buildings. The recycling efforts observed during the building walk-through led to the early conclusion that NREL, as a whole, does a good job with recycling. The physical inventory numbers shown below indicate there is much room for improvement.

	Building 17				SERF			
ITEM	DAY 1	DAY2	TOTAL	AVERAGE	DAY 1	DAY2	TOTAL	AVERAGE
Paper	24	20	44	22	36.5	8	44.5	22.25
Newspaper	6	27	33	33.5	2	4	6	3
Books	0	19	19	9.5	0	0	0	0
Alum/Tin Cans	2	2	4	2	.5	trace	.5	.25
Cardboard	4.5	5.5	10	5	6	6.5	12.5	6.25
Glass Containers	6	0	6	3	trace	trace	0	0
Plastic Containers	2.5	1	3.5	1.75	2	trace	2	1
Packing Peanuts	0	0	0	0	trace	0	0	0
Tyvek	10 pcs	4 pcs	14 pcs	7 pcs	4 pcs	1 pcs	5 pcs	2.5 pcs
Batteries	0	0	0	0	0	0	0	0
Transparencies	3 pcs	8 pcs	11 pcs	5.5 pcs	12 pcs	15 pcs	27 pcs	13.5 pcs
Toner Cartridges	0	0	0	0	0	0	0	0
Scrap Metal	0	0	0	0	trace	trace	0	0
Fluorescent Bulbs	0	0	0	0	0	0	0	0
USGov Mess. Env	16	6	22	11	0	1	1	.5
Total Recyclables	45	74.5	119.5	59.75	47	18.5	65.5	32.75
Non-Recyclable§ Waste	56.5	90.5	147	73.5	70	23.5	93.5	46.75
Total Waste Surveyed	101.5	165	266.5	133.25	117	42	159	79.5
Total recyclables found in waste	44.3%	45.2%		44.8%	40.2%	44.0%		41.2%

• Table 20 Materials Use

NOTES:

UNITS FOR THE ABOVE NUMBERS IN EACH CELL ARE IN "POUNDS" UNLESS OTHERWISE SPECIFIED.

SURVEYS WERE CONDUCTED ON CONSECUTIVE WORKING DAYS FOR EACH BUILDING.

TYVEK AND TRANSPARENCY NUMBERS ARE IN "PIECES" AND ARE NOT INCLUDED IN POUNDAGE TOTALS.

U.S. GOVERNMENT MESSENGER ENVELOPES ARE NOT INCLUDED IN POUNDAGE TOTALS AND WERE OBSERVED TO HAVE (ON AVERAGE) APPROXIMATELY ONE-THIRD OF THE NAME SPACES FILLED.

§ NON-RECYCLABLES INCLUDE GENERAL WASTE INCLUDING FOOD CONTAINERS, FOOD WASTE, BATHROOM WASTE, LAB WASTE, ETC.

Assuming that the numbers shown in the table above are fairly representative of the NREL population, then the average employee generates 0.5 lbs. of garbage every day. Regrettably, on average 43.4% of this waste could be recycled. If these averages are projected onto the whole NREL staff, then approximately 119,375 lbs. of garbage are produced each year by the NREL population. Again, assuming that 43.4% of the waste consisted of materials or items that could have been recycled, then a total of 51,841 lbs. of general waste should have been diverted to recycling. Because such a high percentage of that recyclable material found in the garbage was paper, newspaper, and books (42.4%), this amounts to 25 tons of paper that should have been recycled.

One Ton of Recycled Paper Saves ⁶	NREL Could Have Saved
17 Trees	425 Trees
7,000 Gallons of Water	175,000 Gallons of Water
60 Pounds of Air Pollution	1,500 Pounds of Air Pollution
41kWh of Energy	1,025 kWh of Energy
3 Cubic Yards of Landfill Space	75 Cubic Yards of Landfill Space

• Table 21 Paper Recycling Information

Purchasing Recycled Materials

Regarding the purchase of recycled materials and materials with a high percentage of recycled content, EPA's "designated list" is the current guideline. The table below summarizes FY 99 efforts in this area:

PRODUCT CATAGORY	FY 99 TOTAL PURCHASES (\$)	W/RECOVERED CONTENT (\$)	ADJUSTED TOTAL\$	ADJUSTED % w/RECOVERED CONTENT
Paper and Paper Products (uncoated printing)	62,000	58,900	58,900	100%
Construction Materials (carpet)	89,000	8,900	8,900	10%
Non-Paper Office Products (toner cartridges)	22,218	22,218	22,218	100%

• Table 22 Purchased Recycled Materials FY99

§ ADJUSTED TOTAL IS THE DOLLAR SUM OF THE RECOVERED-CONTENT ITEMS AND UNJUSTIFIED VIRGIN-CONTENT ITEMS. ADJUSTED TOTAL DOES NOT INCLUDE JUSTIFIED PURCHASES OF VIRGIN ITEMS (MADE WHEN THE ITEMS WITH RECOVERED-CONTENT WERE NOT AVAILABLE COMPETITIVELY AT A REASONABLE PRICE OR DID NOT MEET PERFORMANCE STANDARDS).

Because NREL is a paper/research-oriented organization, there are simply not many large volume purchases of many of the items on the EPA list. Further, the online purchasing practiced at NREL currently provides no electronic vehicle for capturing information relating to number of items purchased with recycled content, percentage of recycled content, etc. The purchasing department has made efforts to "reduce" paper requirements; one example is shown in table 23:

⁶ Values from the National Recycling Coalition

YEAR	PURCHASE CARD TRANSACTIONS	PURCHASE ORDER (four sheets per PO) TRANSACTIONS
1995	-0-	9000
1996	Data not available	Data not available
1997	10,800	1875
1998	14,395	1840
1999	13,868	1567

• Table 23 Paper Reduction Example

Tri-R Recycling at NREL

NREL's current recycling efforts are summarized below in the table. These numbers were obtained from TRI-R Recycling. It should be noted that a large percentage of these totals result from NREL employees bringing their recyclables from home, which they have been encouraged to do.

RECYCLED ITEM (DESCRIPTION)	POUNDS RECYCLED IN CALENDER YR 1999
Co-mingled (includes glass, plastic, alum. cans)	21,471 lbs.
Newspaper	40,782 lbs.
Corrugated (cardboard)	12,480 lbs. (ESTIMATE)
Clr. Ledger (colored paper)	8,700 lbs.
Mixed Paper (colored paper, junk mail, envelopes)	68,684 lbs.
White Ledger (8 ½ X 11 computer paper)	2,024 lbs.
Office Pack (White paper)	56,577 lbs.
Destr-Indus (scrap metal)	202 lbs.
TOTAL	210,718 lbs.

• Table 24 Current NREL Recycling Practices

NOTES:

THE CARDBOARD RECYCLING TOTALS COULD NOT BE OBTAINED. TRI-R DOES NOT SHOW ANY CORRUGATED (CARDBOARD) PICKED UP IN FY 99. THIS IS BECAUSE BFI PICKS UP THIS ITEM AND NO WEIGHT RECORDS ARE KEPT. HOWEVER, IT IS KNOWN THAT BFI PICKS UP TWO (2) 6-YARD CARDBOARD CONTAINERS PER WEEK; AND IF THIS TYPE CONTAINER IS FULL OF CARDBOARD, IT WEIGHS APPROXIMATELY 300 POUNDS. IT SHOULD BE NOTED THAT, DURING RANDOM OBSERVATION OF THE DUMPSTERS SERVING THE NREL BUILDINGS, LARGE QUANTITIES OF CARDBOARD WERE SEEN THAT SHOULD HAVE BEEN RECYCLED. OFTEN SHIPPING PALLETS WERE ALSO OBSERVED IN THESE DUMPSTERS. THERE IS NO KNOWN POLICY IN EFFECT FOR DEALING WITH SHIPPING PALLETS.

The estimated economic benefit to the local municipal and state economy is from \$15,909 (low) to \$35,506 (high). These numbers arise from estimates by the National Recycling Coalition of \$151-337/ton of recycled material. These numbers in no way reflect the intangible benefits from recycling such as reduced waste costs, job creation, compliance, public image, etc.

Construction Materials Recycling

Recycled construction materials are purchased on a cost-effective basis. If the cost of the recycled construction material is less than or equal to the cost of the non-recycled construction material, then the recycled material is purchased. Currently, no record of any amounts of the types of materials is kept.

Some examples of recycled construction materials purchased by NREL for its buildings include:

- The carpet in Building 17, the Visitors Center, and the Site Entrance Building.
- The carpet and gypsum board for the new STF to be built in the coming years.

During building demolition for new building construction or for any building renovation(s), concrete, asphalt, carpet, and steel are always recycled. In the past, this was done more for the cost savings than for any desire to recycle, but is still good practice. Generally, recycling construction materials from a demolition site is more cost-effective than hauling the material to the dump. However, this does depend on how close the recycling plant is in relation to the construction site.

Recommendations/Suggestions

- **Locate local vendors in Colorado for recycled materials.** An effort to buy recycled materials and to recycle construction materials is made by NREL. The largest hindrance to the amount of recycled materials purchased or demolition materials recycled is finding local vendors. A local recycling organization, Colorado Recycles, puts out an annual listing of companies in Colorado who buy/take and sell recycled materials. Additionally, the EPA has a great deal of information on how to recycle construction materials. Please see the appendix for a list of EPA publications about construction materials recycling. Also included in the appendices is a list of the more common construction materials being recycled.
- **Collect baseline data on the number of environmentally friendly purchases.** It is felt that a fairly large percentage of NREL purchases are of the environmentally friendly type, but there is no way to know how much.
- **Establish a program for environmentally friendly purchases.** A program should be developed to interface with the online ordering forms and vendor WebPages to capture this information.
- **More education programs on recyclable materials.** Many members of the NREL staff do not know what can and cannot be recycled. Education programs combined with better bin labeling could greatly increase recycling at NREL.
- **Education for janitorial staff.** The janitorial staff currently picks up waste baskets without discretion. Only general waste containers should be collected. Recycle containers should NOT be collected by the janitors.
- **More frequent pickup of recyclable materials from individual buildings.** The large majority of the recycling bins seen during building walk-throughs were

overflowing. These bins need to be picked up more frequently to encourage recycling.

- **Collaborate with Tri-R and local waste-handling company to weigh waste/recyclables when picked up.** This practice is common in many parts of the nation and could/should be implemented here. This would enable NREL to monitor recycling and waste habits.
- **NREL should become a member of the Colorado Association for Recycling.** This organization puts on an annual fair/showcase to unite local recycling companies. This is an excellent resource that NREL should utilize.
- **Purchase Duplexers for Printers.** Duplexers allow printing/copying on both sides of a sheet of paper. This will reduce printer paper use by almost half. It takes 10 times as much energy to produce a piece of paper than to print an image on it.

Hazardous and Other Non-Recycled Waste

The tables below lists the hazardous waste generated by NREL:

MATERIAL	1994	1995	1996	1999	NOTES
Disposed:	(all values in Kg)				
Hazardous Waste	3,180	5,592	3,876	15,251	1999 includes 9,620kg of non-routine waste; 1999 includes batteries
Non-regulated Waste	2,287	1,036	5,014	4,457	Increase largely due to oily waste from 1995 and 1996
Low-level radioactive wastes		9.5	38.6	12	1996 increase due to lab decommissioning
Recycled:	(all values in Kg)				
Used oil	107				Oil disposed because a suitable recycler could not be found locally
Solvents (from parts-cleaning station)	76	68			Parts-cleaning station was not in use in 1996 through 1999
Scrap copper	39	325	64		
Scrap stainless steel	340	295	18		
Scrap ferrous steel	925	3,764	982		Decrease largely due to decreased lab activity in 1996
Aluminum	971	1,739	270		1994 data is Al cans only; 1995 data includes scrap Al and Al cans; 1996 is scrap Al only
Newsprint	9,374	26,117			
White, computer, and mixed papers	28,910	58,717			
Other - batteries	222	6,606	1,818		1995 one-time uninterruptible power supply decommissioning; 1999 batteries are included in hazardous waste figure
Refrigerants			11		Recovered and cleaned for on-site reuse
Pallets			91 ea.		No data collected prior to 1996; given to recycler
Toner cartridges			219 ea.		1996 data for Jan. to mid-Oct; no data collected prior to 1996

• Table 25 Hazardous Waste

NOTE:

1) DATA FOR 1997 AND 1998 NOT AVAILABLE.

Waste Quantities Generated in 1999	
Material Type	Qty in Lbs.
Corrosive Liquids	6,613
Flammable Gas	63
Flammable Liquids	2,217
Flammable Liquids (non-routine)	21,165
Flammable Solid	43
Water Reactive	80
Oxidizer	140
Toxic Materials	3,230
Non-RCRA Regulated	9,805
Low-Level Radioactive	27

• Table 26 1999 Generated Waste Quantities

NREL generated 9,500 pounds of hazardous waste from routine activities in 1999. The quantities listed in the table above are approximations only. These materials are normally not weighed when picked up by disposal or recycling vendors.

It should be noted that a "Waste Management and Minimization Program" does exist at NREL. It was initiated in 1993, and its scope and focus deals mainly with hazardous wastes. The author of this program, John Eickhoff, provided data on hazardous waste disposal and recycling (Table 26). It should also be noted that the Chemical Inventory System has been described by NREL lab personnel as "very good" and ahead of most universities. In addition to the admirable recycling efforts at the Waste Handling Facility, there is also much "reuse" of materials practiced there.

Waste Handling

Waste handling at the leased buildings in the Denver West Office Park is built into the lease agreements. Waste handling at other NREL facilities is summarized below:

NREL waste is picked up by Summit Waste Services. Summit picks up the following containers from various NREL locations:

- Three 30-cubic-yard roll-offs are emptied each week (AFUF, NWTC, and JSF).
- One 20-cubic-yard compactor is emptied each week from the FTLB.
- Three 4-cubic-yard front-loaders are emptied each month (SERF, OTF, and SERL).
- Three 6-cubic-yard front-loaders are emptied each month (NWTC).
- One 30-cubic-yard compactor is emptied each week from the SERF.

This waste is not weighed and no estimates could be obtained. The total annual cost for the above service is \$47,364.

Individual Building Water Use

Indoor Water Use

NREL currently uses indoor water for applications such as drinking, washing, cleaning, showering, and in toilets. Water is also used in buildings for HVAC cooling/heating systems. In addition, the labs at the STM site also use water that has been processed and deionized on site. At both the STM site and JSF, the water comes from the public water supply. At the NWTC, the indoor water is trucked into the site from the Boulder public water supply and stored in tanks.

STM/JSF

Public Water Supply

The water at the STM site has been monitored according to each individual building as the table below shows. Currently the SERF and TTF buildings meet EPA water-efficiency standards. In the past 20 months, the average water usage per month for the entire STM site has been 973,985 gallons costing \$2,741 per month.

BUILDING	GALLONS	WATER (\$)
FTLB	372,845	\$ 928.27
FETA	7,705	\$ 67.12
BTRF	88,935	\$ 217.72
AFUF	65,360	\$ 162.26
MAINT	280	\$ 67.12
S/R	3,790	\$ 67.57
SERF	421,230	\$ 1002.83
OTF	0.00	\$ 67.12
V.C.	10,540	\$ 73.69
SEB	2,315	\$ 20.15
TTF	985	\$ 67.12
TOTAL	973,985	\$ 2740.98

• Table 27 Water Use Averages per Month for past 20 months

Sewer

The STM site sewer costs also have been recorded as shown in the table below. Over the past 12 months the average sewer cost for the STM site has been \$1,848. The sewer cost depends on the amount of water flushed through the system. If water use can be reduced, the sewer cost also will be reduced.

BUILDING	SEWER (\$)
SERF	\$ 1056.00
SEB	\$ 528.00
TTF	\$ 264.00
TOTAL	\$ 1848.00

• Table 28 Average Sewer Costs per Month for past 12 Months

The above data was all that was available on sewer use at NREL at this time. Sewer charges are a function of water use. One of the largest loads fed into the sewer is due to the blow-down from the EVAC cooling towers. In the SERF building, the average blow-down per day is 790 gal. A new chemical process for treating HVAC cooling tower water is being considered. This process would greatly reduce blow-down as well as both water use and sewer costs.

NWTC

Water Supply

The water at the NWTC site is hauled in from the Boulder public water supply by subcontracted water trucks. The water is then stored on site in an underground storage tank (15,000 gallon) and above ground in a water tank (2000 gallon). The water is then distributed to Building 251 and the Industrial User Facility (IUF).

A Water Management Study has been performed on the NWTC using WATERGY computer modeling (see Appendices). The toilets consume almost 50% of the total water use. If these toilets were replaced by 1.6 gpf ULF toilets, it would save 56,000 gallons of water per year. Other possible improvements are shown in the table below.

Improvements	Total Water Usage (gal)	Cost/Year (\$)
Currently	208,000	3,640
Toilets – Replace with ULF1.6 gpf	152,000	2,660
Urinals – Replace with waterless	192,000	3,343
Faucets – Install 1.5 gpm aerators	205,000	3,588
Showerheads – Replace with 2.0 gpm	207,000	3,622

• Table 29 Suggested Improvements from 1999 Water Management Study

Due to the fact that the water is stored in the tanks, an extensive disinfection process is performed at the NWTC (for more details, see NREL Environmental Report for 1999, p. 19, located in the appendices).

Sewer

The NWTC wastewater is treated by two septic systems that include tanks and absorption fields for the treatment of wastewater. For this reason the NWTC site does not incur any sewage costs other than periodic pumping of solids.

Recommendations/Suggestions

- Run WATERGY models for all buildings with large water loads. (See Appendix)
- Install low-flow fixtures wherever possible, especially when replacing broken fixtures.
- Reduce the blow-down on all HVAC water towers using new chemical processes and filtering.
- Follow WATER MANAGEMENT - A Comprehensive Approach For Facility Managers. (See Appendix).
- Collect more baseline data on sewer use and rate structures at NREL. Currently little is known about either.

Outdoor Water Use

NREL's largest concern for outdoor water is ground-water protection. There are testing wells where NREL continues to monitor the quality of water entering and exiting the site. NREL uses only a small amount of water for landscaping purposes.

STM/JSF

Surface Water

Most of the surface water at the STM site drains into Lena Gulch (a tributary of Clear Creek). During times of extended precipitation, the water could be collected in one of the catch basins around campus. At the moment, all of the water in the catch basins simply drains out to Lena Gulch and is not reclaimed for landscaping or other uses.

Ground Water Protection

The STM site has an extensive ground-water monitoring program. Eight testing wells were installed in 1990 at the STM site in order to verify that NREL was not contaminating the water. Since then, three wells have been plugged in accordance with the State of Colorado. No contamination has been found on the STM site, and NREL continues to closely monitor the water (see section 3.3 of the 1999 Environmental Report in the Appendix).

NWTC

Surface Water

The surface water resulting from precipitation at the NWTC drains into many streams in the surrounding area (see NREL Environmental Report for 1999, p. 11). The majority of the water drains into a tributary of Rock Creek.

Recommendations/Suggestions

- **Recycle precipitation.** Reclaim precipitation by storing the water in catch basins for later use in irrigation.
- **Reduce water used for landscaping.** Minimize non-native vegetation so that water use for landscaping purposes is minimized.

Design Goals & Standards for New Construction and Renovation

NREL has policy requiring a limitation of individual building water use. However, during new building design or building renovation, an attempt is made to reduce the amount of water used by NREL. Low-flow bathroom fixtures are present in all buildings and landscaping water needs are kept to a minimum.

Recommendations/Suggestions

- A good guideline for building water use is the EPA standard. The EPA standard would be a good design tool to use during building construction or renovation.

Process Loads

NREL currently has no standard on limiting process loads for individual building water use.

Recommendations/Suggestions

- **Install sufficient water metering so process loads can be monitored.** No separate metering is done for process loads except in the SERF.
- **Set up monitoring of process loads over a certain size.** Reducing the use of large process loads could significantly reduce NREL water use.
- **Charge research tasks directly for water use.** Holding individual groups responsible for their own water use increases the motivation for water conservation.
- **Empower research teams to suggest sustainability pilot programs to minimize water waste.** Enable researchers to take responsibility for reducing their water use.

Building Equipment Loads

NREL currently has no standard on building equipment loads for individual building water use.

Recommendations/Suggestions

- **Develop water-efficiency standards for indoor equipment.** Adhere to current EPA standards for water use in toilets, faucets, showerheads, etc.
- **Require that all new equipment meets the standards.**
- **Purchase only equipment that meets the DOE efficient procurement guidelines.**

General Suggestions, Recommendations, and Comments

NREL should attempt to become the sustainability model for the Department of Energy; this idea should be incorporated into the NREL mission statement.

A “Sustainability Coordinator” position should be funded and the position filled. This person must maintain and expand the current positive momentum toward a sustainable NREL.

Reporting procedures and requirements need to be synchronized and coordinated with the overall Sustainable NREL effort. Now that baseline data has been established, information should be sent in a timely manner to the new sustainability staff so that improvement and progress can be monitored.

Employee training in sustainability is a must for both new and existing staff.

Additional funding should be given to the Recycling Committee to facilitate training and expand recycling practices. New Employee Training and Orientation should be expanded to include recycling.

There are many opportunities for the application of alternative energy devices to buildings on the NREL sites. The economics of most of these projects was not presented as it is an extremely complex and labor-intensive study and therefore beyond the scope of this endeavor. Most of the suggested solar improvements would have an impact on the “peak” electrical requirement. Because 65% of the NREL electrical costs result from peak charges, all proposed alternate energy improvements need to be analyzed.

Improved/additional metering will be necessary to establish more detailed baseline information on electrical and water use. Water metering of the individual systems within buildings (HVAC, process, potable, etc.) needs to be installed. This would allow detailed analysis and WATERGY models to be created that will be necessary to determine where usage problems exist and also where progress is made. Currently, the SERF has individual water meters.

Much of the NREL peak demand that is experienced in July or August is unavoidable. Lighting and HVAC needs must be satisfied. Reducing energy use in the labs during those months especially could reduce the peak demand. Peak charges are based on the highest 15-minute use period. Lab researchers approached reported that most of their colleagues would probably favor a voluntary scheduling and/or coordination of efforts during those peak months so that they could do their part to help reduce these peak electrical requirements. Using vacation time in July/August and voluntary scheduling of short-term high electric power use experimentation via a Web page were some techniques mentioned.

There seems to be no recycling effort at the Joyce Street Facility Warehouse. While it would appear easy to set up a recycling program similar to what exists currently in all NREL buildings, it may be even more worthwhile to look into an “Equipment Inventory System” similar to the Chemical Inventory System. There appears to be millions of dollars in equipment stored in that warehouse. If NREL could participate in (or initiate) an

equipment swapping program with our sister labs, many dollars could be saved. For more information, please see the Second Quarter, 2000, issue of ESAVE (DOE publication).

Establish NREL as a model for an advanced transportation community. Renewable/alternate fuels should power the entire NREL fleet. Executive Order 13149 (section 301) shows the importance of this initiative.

Improve telecommuting and telework strategies. Implementation would result in reduced transportation impact, electrical peak reduction, reduced space requirements, etc. for NREL.

Management could show strong support for the sustainability effort by implementing a "Director's Award for Sustainable Practices". This award would be presented to the employee who best exemplifies sustainable practices in his/her work behaviors, or even in their personal life.

Key Contacts for Baseline Data

GENERAL SUSTAINABILITY INFO AND EXPERTISE

Lynn Billman x3048
Paul Torcellini x7528

MATERIALS FLOW, WASTE, RECYCLING

John Eickhoff	x3217	Hazardous waste, waste minimization, recycling
Randy Cash	x7332	Waste handling, costs
Phil Shepherd	x2929	General expertise on recycling
Don Carlile	x7420	Purchasing practices, affirmative procurement
Don Selmarten	x6609	Recycling committee
Mike Glaser	x7321	Construction materials purchases/recycling/policies
Lori Bird	x7412	Recycling committee
Susan Bilo	x3048	General recycling expertise (DOE)
Ed Weideman	x2923	Building data, site operations
Courtney Essary	303-336-0160	Tri-R Recycling
Kathy Persons	x7344	Janitorial liaison, work control dispatch
Fay Hoover	x4033	Paper procurement

TRANSPORTATION

Barb Goodman	x4455	Alternative and advanced vehicles, ideas, general oversight
Lynn Kaemmerer	x7587	EcoPass statistics
Denise Eckhart	x7340	NREL fleet statistics
Kevin McCorkell	x7586	HR employee addresses, maps-points
Roger Forsyth	x4608	Transportation survey mechanics
Kevin Eber	x3657	General help and guidance, alternative trans. expertise
Lynn Jeka	x4562	Airline travel info, local travel data
John Davis	303-299-2124	RTD statistician

ENERGY

Otto Van Geet	x7369	Energy use by building, electricity/gas bills, etc.
Kerry Shackelford	x7339	Energy management, controls
Ray Jukkola	x7372	Electrical metering project, building electrical modifications
Ben Kroposki	x6170	Photovoltaic use at NREL
Kevin Craig	x2931	Biomass possibilities at NREL
Tom Williams	x7402	Solar thermal/concentrating power possibilities at NREL
Tim Merrigan	x349	Solar hot water possibilities at NREL
Ed Szydle	x6536	SERF Building Area Engineer (BAE)
Chris Gaul	x6161	AFUF-BAE
Bruce Field	x6357	BAE for the following: VC,SEB,OTF,TTF,S/R,MESA
EricTelesmanich	x6102	FTLB-BAE
Ray Hansen	x6177	Work control, general maint. lead technician, small-engine fuel
Jim Johnson	x6989	Site operations engineer at NWTC

WATER

Otto Van Geet	x7369	Water use by building
Trina Brown	x7518	General expertise and experience in water-use studies

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LIST OF ABBREVIATIONS IN ORDER OF APPEARANCE

NREL – National Renewable Energy Laboratory
AFUF - Alternate Fuels User Facility
FTLB – Field Test Laboratory Building
NWTC – National Wind Technology Center
OTF – Outdoor Test Facility
SEB – Site Entrance Building
SERF – Solar Energy Research Facility
TTF – Thermal Test Facility
JSF – Joyce Street Facility
WHF – Waste Handling Facility
VC – Visitors Center
STM – South Table Mountain
RTD – Regional Transportation District
PSCo – Public Service Company (gas and electricity provider)
PV – Photovoltaic
DOE – Department of Energy
GSA/Tiger – Natural Gas Provider
KW – Kilowatt
KWHR – Kilowatt Hour
MMBTU – One Million British Thermal Units
PDU – Process Demonstration Unit
DWOP – Denver West Office Park
LEED – Leadership in Energy and Efficient Design
FEMA – Federal Emergency Management Administration
CFR – Code of Federal Regulations
LBL – Lawrence Berkeley Laboratory
HVAC – Heating, Ventilating, and Air Conditioning
EPA – Environmental Protection Agency
CFC – Chlorinated Fluoro-Carbon
ES&H- Environment, Safety, and Health
Tri-R – local recycling company
Kg – kilogram
RCRA – Resource Conservation and Recovery Act
IUF – Industrial User Facility
gpf – gallons per flush
ULF – Ultra-low Flow
EPACT – Energy Policy Act
BAE – Building Area Engineer
S/R – Shipping and Receiving